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Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART II UNDERGROUND EXCAVATION IN ROCK

Section I Drilling and Blasting

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 1

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CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART: II UNDERGROUND EXCAVATION IN ROCK

Section I Drilling and Blasting

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Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART II UNDERGROUND EXCAVATION IN ROCK

Section I Drilling and Blasting

0. FOREWORD

0.1 This Indian Standard (Part II/Section 1) was adopted by the Indian Standards Institution on 26 October 1970, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The construction of tunnels involves a large number of problems. Because of the great longitudinal extent of the work many different kinds of conditions are encountered which for maximum economy should be treated differently. This standard covers recommendations which would be generally applicable to construction of tunnels, for the assistance of engineers engaged on such projects. This standard should, however, be used with caution since due to the very nature of the subject it is not possible to lay down detailed specifications to cover each and every possible case and the discretion of the engineer-in-charge would be required in many cases.

0.3 This standard will be published in parts. The other parts of this standard are as follows:

Part I Precision survey and setting out

Part III Underground excavation in soft strata

Part IV Tunnel supports

Part V Concrete lining

Part VI Steel lining

0.3.1 Part II will be published in sections. Other sections of this part will cover ventilation, mucking, lighting, dewatering and tunnelling methods for steeply inclined tunnels and shafts.

0.4 Other related standards printed so far on this subject are given below:

IS : 4081-1967 Safety code for blasting and related drilling operations

IS : 4138-1967 Safety code for working in compressed air

IS : 4756-1968 Safety code for tunnelling work

IS : 4880 (Part II)-1968 Code of practice for design of tunnels conveying water: Part II Geometric design

IS : 4880 (Part III)-1968 Code of practice for design of tunnels conveying water : Part III Hydraulic design

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final values, observed or calculated, expressing the results of a test or analysis, shall be rounded off in accordance with IS: 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified values in this standard.

1. SCOPE

1.1 This standard (Part II/Section 1) deals with drilling and blasting for underground excavation of tunnels in rock.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 **Adit** — A tunnel or open cut driven from the surface to add to the number of working faces of the main tunnel.

2.2 **Benching-The** operation of removal of the lower portion of the tunnel profile after the top heading has been excavation and where drilling vertically down is possible.

2.3 Cover — Cover on a tunnel in any direction is the distance from the tunnel soffit to the rock surface in that direction.

2.4 Cut — The group of holes fired first in a round to provide additional free faces for the succeeding shots.

NOTE — **This definition applies only to drilling patterns.**

2.5 **Detonator** — A device for producing detonation in a high explosive charge, and initiated by a safety fuse or by electricity.

2.6 **Drift** — A horizontal tunnel usually of a small cross-section and length driven either from surface for exploration purpose or from an underground face for any purpose.

2.7 **Drill Carriages-A** vehicle on which one or more drill booms are mounted to permit the drills to be brought easily to their work site and to be removed before blasting.

2.8 **Drilling Pattern-** It is an arrangement showing location, direction and depth of the holes drilled into the face of a tunnel.

***Rules for rounding off numerical values (revised).**

2.9 Easer — Ring of holes drilled around cut holes and fired after cut holes.

2.10 Explosive — Any mixture or chemical compound which is capable of producing an explosion by its own energy. This includes black powder dynamite, nitroglycerine compounds, fulminate or explosive substance having explosive power equal to or greater than black powder.

2.11 Heading — The face of the tunnel where actual tunnelling operations are in progress. However, when it is prefixed by 'top' or 'bottom' it denotes a part section excavated in advance in the line of the intended tunnel.

2.12 **High Explosive** — An explosive which explodes with detonation and detonates at velocities varying from about 1 500 to 7 500 m/s, and produces large volume of gases at exceptionally high pressure.

2.13 **Jumbo** — A mobile platform with number of decks used at the heading of large size tunnels for drilling and also for scaling, erection of roof supports, guniting, shotcreting, etc.

2.14 **Mucking**- The operation of removal of the blasted stones/material after the blast has taken place.

2.15 Overbreak — The portion blasted beyond the lines of theintended section.

2.16 Primer — The explosive cartridge into which the detonator has been inserted.

2.17 Scaling — An operation to remove all loose bits of rock from the blasted surface, after the blasting is over.

2.18 Shaft **and Steeply Inclined Tunnels** -These are vertical or inclined tunnels in which self-propelled hauling equipment, running on the invert of the tunnel cannot be used.

2.19 Stemming — Inert material packed between the explosive charge and the outer end of the shot hole.

2.20 Stoping — Operations for overhead excavation by drilling from an underground face.

2.21 Trimmer — Holes at the periphery of an excavation, fired to give the excavation its final outline.

3. GENERAL

3.1 Preliminary work required to establish a tunnel face consists of mainly the following items:

a) Open excavation in overburden and rock or excavation of a shaft from the bottom of which the tunnel excavation can start;

b) Arrangement for collection of surface water and. ts drainage by gravity or pumping;

c) Access roads or rail tracks to mucking areas;

d) Erection or winching and hauling equipment; and

e) Establishment of a field workshop, compressors, pumps, water lines, ventilation fans, ducts, etc.

3.2 **Location of Portal-The** portal, that is, the face from where a tunnel starts has to be decided with reference to the rock cover. The minimum cover with which tunnel can be started depends on the type and structure of rock mass, the size and shape of the tunnel and the pressure of the water in case of **hydro-tunnels.**

3.2.1 The length up to which it is economical to adopt an open cut in preference to a tunnel depends on the cost of underground and open excavation, and the cost of protective works involved.

3.2.2 In some cases, the cost of protective works in open cuts becomes very high. However, open excavation has to be continued up to a point where adequate rock cover is available. Under such circumstances cut and cover sections are found more suitable.

3.2.3 Before taking up the excavation of a tunnel its face shall be established and alignment of the tunnel marked in accordance with IS:5878 (Part I)-1970".

3.3 **Shape' of Tunnel** — The selection of shape of tunnel may be made conforming to IS : 4880 (Part II)-1968†.

3.4 **Tunnelling Methods** — The method of attacking the faces of tunnel depends on the size and shape of the tunnel, the equipment available, the condition of the formation and the extent to which supports are necessary and overall economics. The common methods of attack are given in **3.4** to 3.4.4.

3.4.1 *Full Face* — This method is generally recommended for tunnels in good rock.

3.4.2 Top *Heading and Benching* — This method is generally recommended where the tunnel section is very large and/or the rock is not structurally sound (see Fig. IA). The heading may be excavated to full length or part length of the tunnel as may be suitable.

*Code of practice for construction of tunnels : Part I Precision survey and setting out.
†Code of practice for design of tunnels conveying water : Part II Geometric design.

3.4.3 Bottom ***Heading and Stoping*** — **This method is generally recommended where the tunnel section is very large and the rock is consistent and sound (*see* Fig. 1B).**

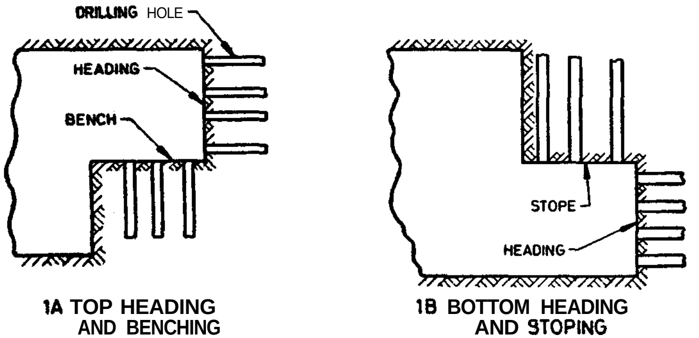


FIG. 1 HEADING AND BENCHING/STOPING

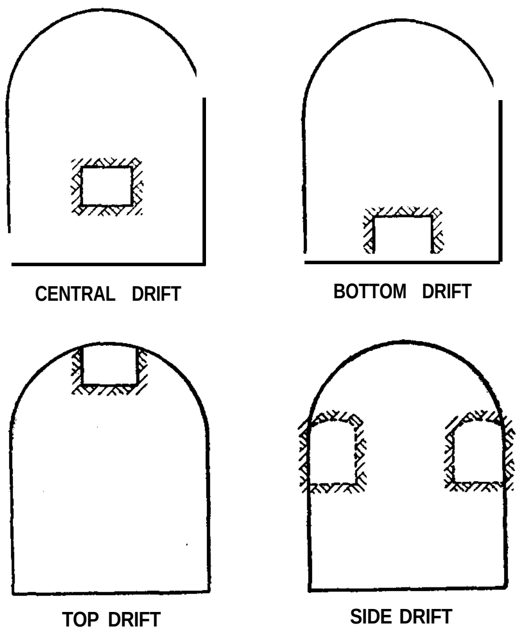


FIG. 2 DRIFT METHOD

3.4.4 *Drift Method*-In driving a large tunnel, it may be economical to drive a small tunnel, called a drift or a pilot tunnel prior to excavating the full bore. A drift may be classified as centre, bottom, side or top depending on its position relative to the main bore (see Fig. 2).

3.5 Sequence of Operations for Construction of tunnels

3.5.1 The actual operations in the construction of a tunnel may vary with the type and size of tunnel, method of attack and the kind of formation encountered.

3.5.2 For a tunnel driven in rock, following operations are normally required:

a) Marking tunnel profile;
b) Setting up and drilling;
c) Loading explosives and blasting;
d) Removing the foul gases;
e) Checking misfires;
f) Scaling;
g) Mucking; and
h) Guniting, erecting supports or rock bolting and lining, if and when necessary.

4. DRILLING

4.1 General — For driving a tunnel through rock it is essential to drill holes for charging the explosives. The drilling pattern should be worked out by experiments for each particular work as it depends on the texture and formation of rock, size and shape of the tunnel, the strength of explosives and also the fragmentation of rock required so as to make it suitable for handling by mucking equipment. The drilling should be such as to ensure minimum overbreak and least amount of explosive per unit volume of excavation. Adequate safety precautions shall be taken during drilling operations in accordance with IS : 4081-1967*.

NOTE — Presplitting is a recent technique of smooth blasting that offers possibility of applying low charges of instantaneous ignition, which develops a crack in a pre-determined line of holes and results in reduction in overbreak and ground vibrations. Such cracks for the final contour are created by blasting prior to the drilling of the rest of the holes for the blasting pattern. Once the crack is made, it screens off the surroundings to some extent from the ground vibrations due to the main round. The presplitting method involves extra meterage of drilling and is mostly used in open cut excavation. This method has not so far been used in tunnelling.

*Safety code of blasting and related drilling operations.

4.2 Equipment — Holes shall be drilled by using pneumatically operated rock drills in conjunction with pneumatic pushers and/or auto feeds with ladders or drifters mounted on column bars or drill carriages, as may be found suitable. Only wet drilling shall be permitted. Number of drills is governed by the area of the face of the tunnel. It is generally recommended that one drill may be used for each 4 to 5 m^2 face area.

4.3 **Diameter of Holes** — The diameter of hole at its deepest point shall be at least 6 mm more than the diameter of the cartridge.

4.4 **Drilling Pattern** — It consists of the following holes which are detonated in-the order given below:

a) Cut holes,

b) Easers, and

c) Trimmers.

4.4.1 *Cut Holes* -*The* cut holes are usually provided in the centre of the round 15 to 30 cm deeper than the other holes and are drilled converging towards the centre of the face with the idea of producing an initial cone, or wedge as a free face for breaking off succeeding holes. The other holes are arranged around the cut holes. The position of the cut holes is governed by the following factors:

a) In order to restrict the throw of the blasted rock from the cut holes these should be placed as low as possible;

b) When electrical firing is adopted and the choice of different delay intervals is limited, cut holes should be placed in the centre;

c) In order to get the maximum possible advance in narrow tunnels cut holes placed on side should be tried.

4.4.2 Some of the general drilling patterns are given in 4.4.2.1 to 4.4.2.6.

4.4.2.1 *Horizontal wedge cut* — The holes are placed symmetrically with respect to the vertical centre line of the section (see Fig. 3). The drill holes are horizontal and the angle towards the working face is large, and, therefore, is easy to drill. This cut is generally recommended for almost all sizes of tunnels except in very small tunnels. With wedge cut, it is not possible to obtain advances more than half the width of the tunnel as it is not possible to drill cut holes with the requisite angle to a greater depth than half the width of the tunnel.

4.4.2.2 *Pyramid cut* — In this type (see Fig. 4) three or four converging holes are so directed that they meet at a point further in, This cut is generally recommended for small size shaft sinking.

4.4.2.3 *Fan cut* — In this type of cut (see Fig. 5) the cut holes are shifted to one side of the tunnel, and the cut holes and adjacent holes are drilled

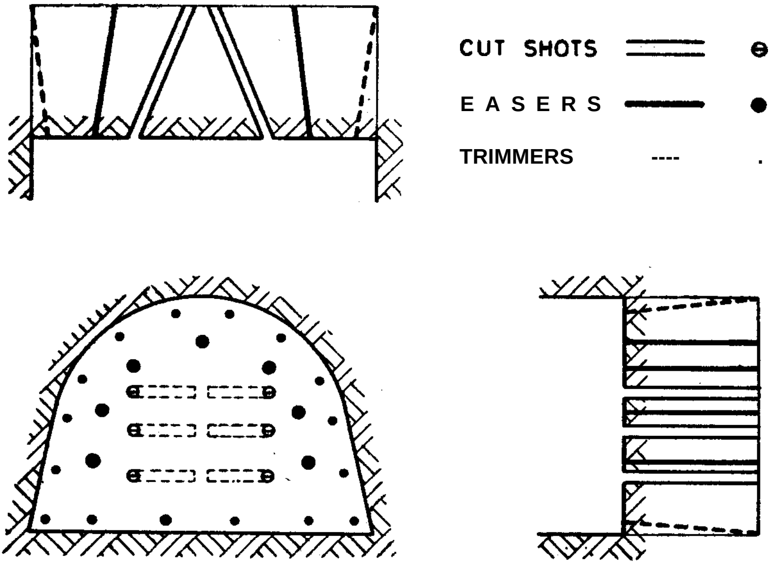


FIG. 3 HORIZONTAL WEDGE CUT

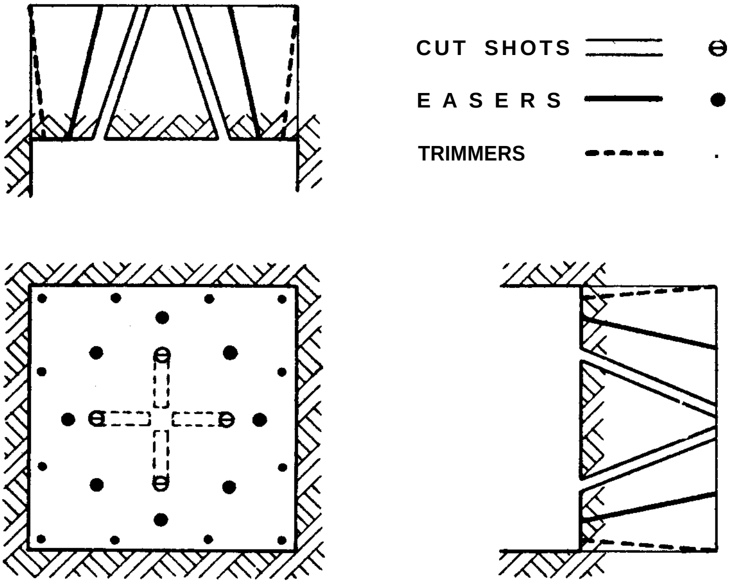
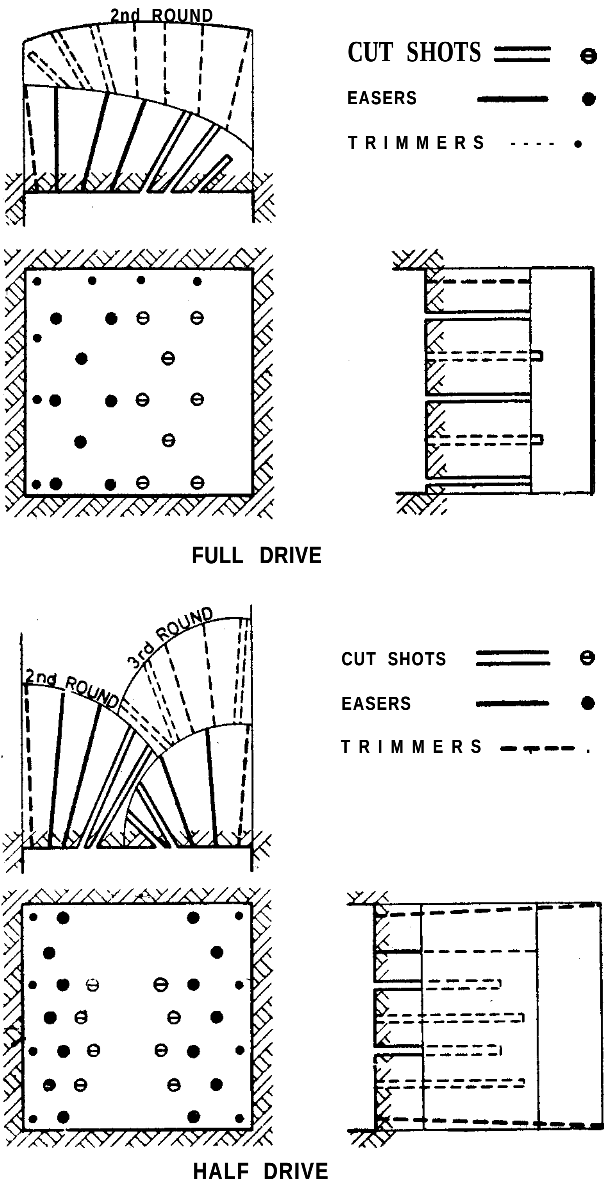


FIG. 4 PYRAMID CUT


2nd ROUND
CUT SHOTS
EASERS
TRIMMERS
FULL DRIVE
3rd ROUND
2nd ROUND
CUT SHOTS
EASERS
TRIMMERS
HALF DRIVE

Fro. 5 FAN CUT

into fan shape. This cut is generally recommended for small tunnels, when it is not possible to drill a deeper wedge cut due to the restricted width. The cut holes should be drilled on alternate sides in each blast.

4.4.2.4 *V-cut* — This cut (see Fig, 6) is **practically** similar to horizontal wedge, but is suitable for tunnels of very large sections. It is generally recommended for tunnels for 30 to 100 m^2 in cross-sectional area. In this case the position of the cut holes is determined by the design of the drilling jumbo.

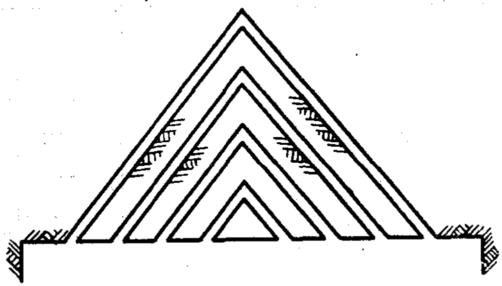
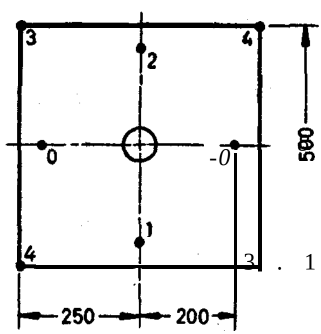


FIG. 6 V-CUT

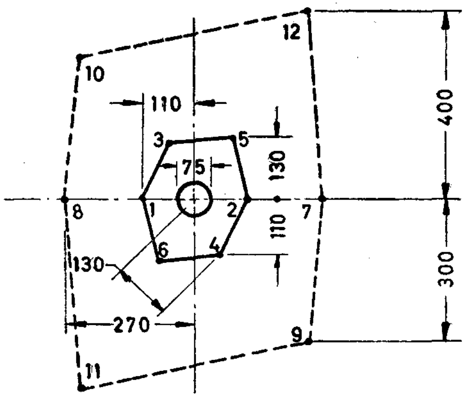
4.4.2.5 *Michigan or cylinder cut* — In this type (see Fig. 7) a hole of larger diameter as compared to other cuts, ranging from 7 to 10 cm is to be drilled in the centre. Around this hole, another series of holes forming



,411 dimensions in millimetres.

FIG. 7 MICHIGAN CUT

two pentagons or two triangles are drilled close to the central holes. The rest of the holes are drilled as usual. The central hole is not to be loaded while the rest are loaded and blasted in such a manner that the holes close to the central holes blast first. By this method more advance can be achieved in small tunnels of about 10 m^2 cross-sectional area, where on account of less width the length of cut holes into wedge shape is limited. This type of cut entails the largest drilling metrage per cut and a heavier consumption of explosives than the other types. Double spiral cut and coromont cut are similar to michigan cut and are illustrated in Fig. 8 and 9.

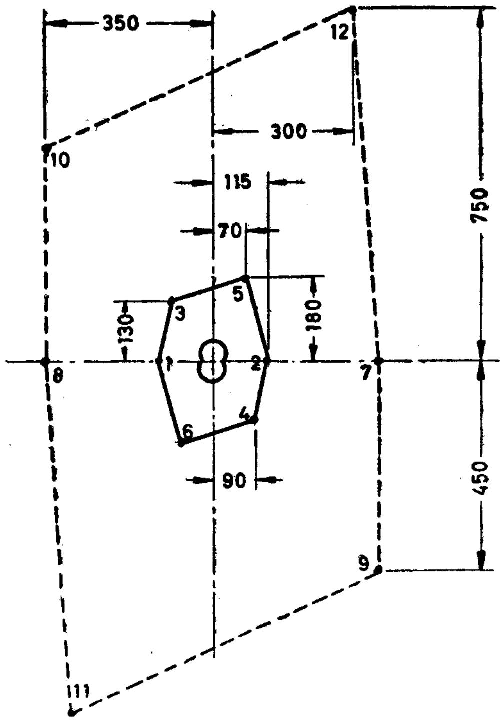


All dimensions in millimetres.

FIG. 8 DOUBLE SPIRAL CUT

4.4.2.6 Burn *cut* — This is somewhat similar to michigan or cylinder type cut (see Fig. 10). All the holes are at right angle to the tunnel face. There are many variants in this type. In one variant the charged holes are located inside the cut holes and are broken towards the surrounding uncharged holes. In other variant the charged and uncharged holes alternate with one another according to the form of vertical seam. The type of cut is easy to drill and is generally recommended for tunnels up to 20 m^2 in cross-sectional area. For homogeneous rock this is more suitable.

4.4.2.7 The cylinder cuts and the burn cuts utilize parallel holes and usually give better advance per round than the wedge, *V*, pyramid and fan cuts. The practical difficulties of these cuts, however, are that they require two different types of equipment at the face, one for drilling the empty holes (usually 75 to 125 mm) and one for drilling the loaded holes (usually 30 to 35 mm). They require special templates to accurately drill the holes



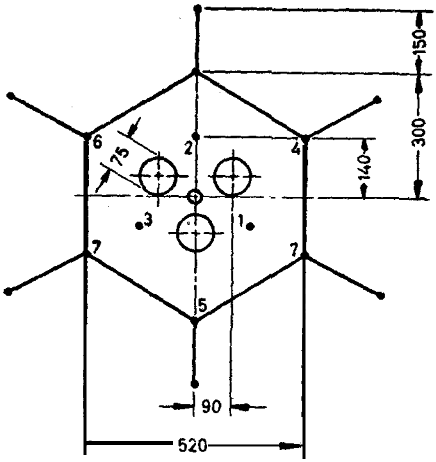
NOTE-Two central holes of 57 mm dia each.
All dimensions in millimetres.

FIG. 9 COROMONT CUT

to the correct pattern. Moreover the total number of holes drilled are more and the consumption of explosives is also mere. They can be used only where reliable millisecond delay detonators are available. These are recommended only where the greater advance is proved economical and where facilities for drilling bigger holes are economically available.

4.4.3 *Easers* — The function of these holes is to blast the area around the cone/wedge created by cut holes and thereby reduce the burden on other holes. Charge in these holes is lesser than in cut holes which carry the heaviest charge. These are located around cut holes. Easers may be primary or secondary.

4.4.4 *Trimmers* — These are along the perifery of the profile and are provided to give the section the required shape. These carry comparatively lighter charge to avoid excessive overbreaks.



NOTE - Burn cut with three 75-mm empty holes and six outer cut holes. All dimensions in millimetres.

FIG. 10 BURN CUT

5. BLASTING

5.1 Explosives — High explosives are used for tunnelling operations. The strength of high explosives is expressed as a percentage of the strength of blasting gelatine which is the most powerful of commercial explosives.

5.1.1 The following types of explosives are recommended for use in tunnelling operations:

a) ***Blasting gelatine*** — It has the highest concentrated power and it is used for blasting very hard and tough rocks. This is fully waterproof and adaptable to wet work.

b) ***Special gelatines 90 percent to 40 percent*** — These are characterised by gelatinous *consistency,* high density, freedom from noxious fumes and good storage properties. The requisite strength of gelatine may be selected to suit the actual rock conditions which may vary from very hard to soft rock. For use at high altitudes, low freezing types of gelatines may be used.

c) ***Ammonia dynamite-These*** types of explosives *contain* equal amount of nitroglycerine and nitrate of ammonia. They are made in strengths from 15 to 60 percent. They are not so sensitive or so quick and shattering as straight dynamite. They are recommended for soft rock.

d) ***Semi-gelatine*** — They *contain* nitrateofammonia, gelatinised nitroglycerine and nitro-cotton. They are bulkier than the other varieties and come in only two strengths, 45 and 60 percent. They are water resistant and the fumes are not so bad as that of straight dynamite. Because of their low density they are cheaper, and are recommended for soft rock and limestone.

5.1.2 Almost all the types of explosives are packed in wooden/fibre board boxes containing 25 kg net weight and are manufactured in cartridges ranging from 25 to 63 mm dia and 200 to 245 mm length.

5.2 **Detonators** -These are of the following two types (see 2.5):

a) Ordinary detonators; and

b) Electric detonators, instantaneous, and delay detonators.

5.2.1 *Ordinary Detonators* — An ordinary detonator comprises a small aluminium tube closed at one end and containing a small charge of one or more highly concentrated explosives. This charge can be initiated by the flame from a safety fuse and in turn it detonates the high explosives charge in which the detonator tube is embedded. Since ordinary detonators are always initiated by a safety fuse, they cannot be used to fire a large number of shots simultaneously.

5.2.2 *Instantaneous Electric Detonator-The* electric detonator provides the means for initiating the explosive charges electrically. It consists of an aluminium or copper tube containing a small explosive charge, with its open end sealed with a neoprene plug through which the leading wires of the fuse head assembly pass. The explosive charge is initiated by the flash of the fuse head which occurs when electric current passes through the fuse head. The leading wires are generally of 1·8 m length but detonators wits longer leading wires are also available. Instantaneous electric detonatorh permit firing of a group of holes simultaneously.

5.2.3 *Delay Detonators* — The delay detonator consists basically of an electric detonator with the proper delay element interposed between the fuse-head and the charge. Delay detonators are of the following two types:

a) Short delay or milli-second delay detonators, and

b) Long delay or half second delay detonators.

5.2.3.1 *Short delay or milli-second delay detonators-These* are available in delay numbers of 0 to 6 with a nominal delay interval of 25 milliseconds; these can be used in tunnelling as well as open excavations. The advantages of their use are as follows:

a) Much better fragmentation is obtained;

b) Secondary blasting is reduced to minimum;

c) There is more uniformity in the size of fragmentation;

d) The amount and direction of the pull can be better controlled; and

e) The most outstanding advantage is that more holes can be fired in a single blast with less vibration, concussion and noise.

5.2.4 ***Long Delay or Half Second Delay Detonators*** — These are available in delay series or 0 to 10 numbers with a nominal delay interval of 300 milliseconds (500 milliseconds in case of half second delays).

5.3 **Safety Fuse** — It consists of a train of black powder tightly wrapped and enclosed in various coverings and waterproofing materials and conducts a flame at uniform rate to a detonator for the firing of an explosive charge. It has a limited use in tunnelling operation. The burning rate of fuse shall be not more than 60 cm/min.

5.4 **Detonating Fuse**- Contains a high explosive core with a waterproof covering. It has a high velocity (6 500 m/s), good tensile strength, is light and flexible. It is used for shooting a large number of holes in one blast. Detonating fuse is detonated by the use of one or two blasting caps securely attached alongside it.

5.5 **Primer** -A primer is a cartridge containing the detonator. The detonator should be placed well within the cartridge and parallel to its axis.

5.6 **Circuit Testers** — It is absolutely necessary to test every electric detonator and also the circuit. For this purpose safety ohmmeters are available. To test an electric detonator, it should be placed inside an iron pot or tube to guard against accidental explosion. The open ends of the leading wires are to be connected with the terminals of the ohmmeter and if the needle deflects, and shows the correct resistance of the detonator, it indicates that the circuit is complete, and detonator is in order.

5.7 **Loading and Stemming**

5.7.1 Loading- Before loading is started, each hole shall be blown out with a high pressure air jet to remove loose cuttings and water. In tunnels equipped with drill carriages when holes are loaded from the platforms, all light and power lines shall be disconnected from the carriage. For lighting the face during loading, flood lights may be fixed at a safe distance from the loading zone. During loading, precautions in accordance with IS : 4081-1967* shall be taken.

5.7.1.1 Primer cartridge may be placed next to the bottom. A full cartridge should be inserted first, tamped well into the bottom, then primer shall be inserted with the end containing detonator pointing towards the bottom of the hole; both the primer and the next placed cartridge shall be tamped lightly to prevent jarring of the detonator. The remaining cartridges shall be then tamped firmly in place with a wooden pole, taking care to prevent breaking of the detonator wires. In no case, iron or steel device shall be used for tamping.

*Safety code for blasting and related drilling operations.

5.7.2 *Stemming*- The remainder of the hole not occupied by explosives shall be filled with an inert material (see **2.19**) and tightly tamped. The use of soft rolled plugs of clay is recommended. A damp mixture of sand and clay, either packed in paper bags or loose may also be used. A rubber plug with a wooden core is also often used.

5.8 **Electrical Wiring Used for Blasting**—The different wires used in electric blasting circuits are mentioned below:

a) *Leading Wires or Leg* Wires-These are insulated wires that extend from the end of a detonator. Lengths of leading wires range from 1·8 m to 20 m depending upon requirements. The bare ends of, leading wires shall be kept short circuited as a precaution against accidental detonation due to stray currents.

b) *Connecting* Wires-These are insulated wires which are sometimes required to complete the circuit between the leading wires of adjacent detonators or between the detonators and the shot firing cable.

c) *Shot Firing Cable* — It is used to connect the source of power to the detonator circuit. The cable should be well insulaled two core cable approximately 300 m long, each core consisting of a conductor of at least 4 copper wires of not less than 0·46 mm diameter.

5.9 Blasting Circuits — There are three general types of blasting circuits, namely, (a) series, (b) parallel, and (c) combination, that is parallel series.

5.9.1 In series circuit, the leg wires from adjacent holes are so connected that the path of current is through each blasting cap or detonator in succession. This circuit is used for small number of caps (see Fig. 11).

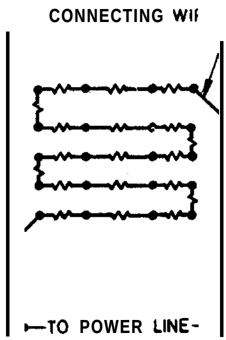


FIG. 11 SERIES CIRCUIT

5.9.2 In the parallel circuit, each of the two leg wires is connected to the core of the main shot firing circuit (see Fig. 12).

5.9.3 In parallel series circuit, groups of series connections are connected in parallel (see Fig. 13).

5.9.4 The connection between leading wires of the detonators and the shot firing cable (or connecting wires) shall be made tightly and kept away from the ground/water. In parallel series circuit it is necessary to place the same number of caps in each series.

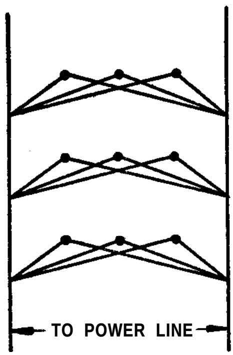


FIG. 12 PARALLEL CIRCUIT

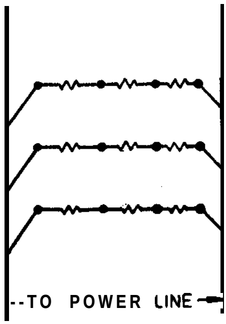


FIG. 13 PARALLEL-SERIES CIRCUIT

5.9.5 After all connections are made, the circuit shall be checked with an ohmmeter. If the circuit is complete and the connections are correctly made the meter will show the appropriate reading of the resistance of the circuit (see 5.11). However, if the circuit is incomplete, the ohmmeter will indicate infinite resistance; the fault or the break in the circuit can be located in the following manner:

> Examine the circuit for any faulty connections. If the fault is not detected by this process, split the circuit into two halves. Test these halves individually for continuity using an ohmmeter. Divide the defective half of the circuit, indicated by the test, into two halves again and repeat the test till only 4 or 5 detonators remain in the faulty circuit. Each detonator in turn should then be tested to find the fault. Having located the faulty detonator in this manner, the remainder of the circuit should be connected and fired leaving out the faulty detonator. The undetonated shot should be treated as a misfire and dealt with accordingly. Until the circuit is tested and found correct, nc attempt shall be made to fire the round.

5.9.6 Connecting wires shall be connected to the two cores of the main shot firing cable that is carried on the side of the tunnel opposite to the location of light and power lines.

5.10 **Firing Circuit** — The location of the firing stations should be safe. In short tunnels where heading is short, the firing switch shall be located outside the tunnel at the top of shaft or outside the portal clear of possible flying rock. In long headings, the switch shall be at least 300 metres away from the face.

5.10.1 Current for firing the blast may be obtained from (a) power circuits, (b) an exploder, that is, an electric generator, operated by hand, or storage, or dry cell batteries& Power circuit voltage may be 440 V, though 220 V and 110 V are also often used.

5.10.1.1 Storage or dry cell batteries are not recommended generally because of their low voltage and because they are subject to constant deterioration.

5.10.1.2 In case of firing from power lines, in order to avoid fluctuations in the voltage and current, it is advisable to use an individual ungrounded circuit and not the same line that supplies current to other equipment.

5.10.1.3 The so called 30 and 50 shot machines which are actuated by vigorously pushing down a rack bar; can fire 30 and 50 caps connected in series respectively.

5.10.1.4 The newer portable machines are 'Condenser-discharge' machines designed to fire multiple shots at one time. The condensers are charged by turning a hand crank, to spin the armature of a dc generator. When the condensers are full charged as indicated by a lamp, the blasting circuit may'be fired by closing a switch on the blasting machine to discharge the condensers.

5.11 Electrical **Resistance** — In case of a series Circuit, a current of at least 1·5 A of dc or 3 A of ac is suggested. Resistance of various caps and the leg wires attached to them are specified by the suppliers. Knowing the total resistance in the circuit caps, leg wires, connecting and shot firing cable together, voltage required to fire the blast is arrived at by using Ohm's law:

$$E = IR$$

where

E = voltage in V,

I = current in A, and

R = resistance in Ω.

5.11.1 Either direct or alternating current may be used; but alternating current of less than 50 cycle frequency is not recommended.

5.11.2 In case of parallel circuit, each cap require 0·6 A current. Connecting in parallel reduces the resistance of the system.

5.11.3 In case of parallel series circuit, each series required a current of 1·5 A; the total current required will be 1·5 A x No. of series. The cap resistance of each series may be calculated. The total, resistance of the system will be resistance of each series divided by the number of series.

5.12 Adequate safety precautions shall be taken during transportation, storage and use of explosive, firing, shooting with fuse, etc, in accordance with IS : 4081-1967* and IS : 4756-1968†.

5.13 Inspection and Handling Misfires — Immediately after the smoke is cleared away from a blast, the results shall be inspected by a competent experienced tunnel-foreman.

All loose rock shall be removed carefully by barring, so as to ensure that the access to the face is safe.

A careful inspection of the face shall then be made to check misfires. Working near a misfired hole is the most dangerous operation in tunnelling. Investigations and correction shall be, therefore, left to a careful and experienced man.

Misfires may be due to improper primers, use of non-water resistant explosives in wet conditions, improper loading causing injuries to fuse or leg wire, bad connections, etc. Inspection of blasting and misfires shall be carried out in accordance with IS : 4756-1968†.

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*Safety code for blasting and related drilling operations.
†Safety code for tunnelling work.

AMENDMENT NO. 1 MARCH 1977

TO

IS:5878(Part II/Sec 1)-1970 CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS

PART II UNDERGROUND EXCAVATION IN ROCK

Section 1 Drilling and Blasting

Alteration

(First cover page, ***pages 1 and*** 3, ***title)*** - Substitute the following for the existing title:

'***Indian Standard***
CORE OF PRACTICE FOR CONSTRUCTION
OF TUNNELS CONVEYING WATER

PART 11 UNDERGROUND EXCAVATION IN ROCK

Section 1 Drilling and Blasting'

(BDC 58)

Reprography Unit, ISI,New Delhi